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Yield potential and soil quality under alternative crop production practices for fresh market pepper

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Abstract

This study was conducted in Florida in 1999 and 2000 to examine the impact of alternative crop production practices on soil quality and yields of fresh market pepper (*Capsicum annuum*). Replicated field plots were established on an organic vegetable farm that had been under certification for 5 years and on a conventional pepper farm that had been fumigated with methyl bromide for 25 consecutive years. Production practices evaluated included raised beds covered by white plastic mulch, soil solarization, no-till in a stubble crop of sunn hemp (*Crotolaria juncea*) or iron-clay pea (*Vigna unguiculata*) and the addition of 67 t ha^{-1} of urban plant debris (UPD). Soil fumigation with methyl bromide–chloropicrin was also evaluated at the conventional farm site. Soil organic carbon significantly increased following the addition of UPD in both years at the organic site but only in the second year at the conventional site. Cation exchange capacity increased significantly after addition of UPD in both years at both sites and a significant interaction with production practices was observed in the second year at the organic site. Soil phosphorus levels were high at both sites but were not impacted by production practices or UPD. In 1999, the addition of UPD significantly decreased soil nitrate levels at the organic site and the conventional site, except under the no-till treatments. In 2000, soil nitrate levels were not affected by UPD or production practice. Stand counts, determined by the number of surviving pepper plants 21–28 days after transplanting, were severely impacted in no-till treatments due to intense competition from weeds. Marketable yields equal to, or above, the 1999/2000 statewide average for conventional production systems were obtained with soil fumigation and soil solarization at the conventional site in 1999. In 2000, an epidemic of *Phytophthora* blight (*Phytophthora capsici*) eliminated production at the conventional site. Marketable yield at the organic site approached the statewide average for conventional systems under the solarization treatment. Yields under plastic mulch were increased at both sites with the addition of UPD. The results demonstrated that organic pepper yields from soil-solarized plots were similar to yields obtained by conventional farmers using high inputs of rapidly mobile nitrogen sources. However, no-till systems for fall production do not appear to be a viable alternative under Florida conditions due to the rapid proliferation of weeds under the cover crop stubble. The addition of urban plant debris was associated with an increase in soil organic carbon and cation exchange capacity in sandy soils typical of those found in Florida.

Key words: conservation tillage, cover crops, methyl bromide, organic agriculture, pepper, soil solarization

Introduction

Florida is the leading producer of fresh market tomatoes (*Lycopersicon esculentum*) and peppers (*Capsicum annuum*) in the United States. Combined, the two crops have an annual value exceeding $US751 million[1]. Production areas within Florida have humid, subtropical climates receiving 145 cm of annual precipitation. The sandy soils are low in fertility, contain little organic matter and have low cation exchange capacity (CEC). To maintain high crop yields under these conditions, conventional commercial growers rely upon complex production systems requiring high inputs of rapidly mobile N and K sources,

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plastic mulch, herbicides and broad-spectrum fumigants[2,3]. The continued use of these management tools is uncertain. Many popular soil fumigants such as ethylene dibromide (EDB) or 1,2-dibromochloropropane (DBCP) are no longer labeled for crops in the USA, and the use of other popular fumigants, such as 1,3-dichloropropene or methyl bromide, has been restricted due to environmental and worker exposure hazards. Herbicide resistance has been reported for 162 plant species and 272 biotypes, many of which are common to the Florida production region[4]. Expansion of agriculture is limited by rapid urbanization and increased land costs. Additionally, consumer demand for organic or pesticide-free produce has risen dramatically[5] and may significantly impact marketing of conventionally grown produce.

Organic production systems provide some alternatives to the conventional production systems used by Florida growers. Van Bruggen[6] reviewed comparative studies examining the severity of soilborne diseases in organic and conventional farms and concluded that root diseases were generally less severe in organic and reduced-input farms. Disease suppression in organic systems is commonly associated with increased microbial and microfauna activity resulting from the regular application of organic amendments and reduced levels of pesticides[7,8]. In spite of the success of conventional industry, production in Florida accounts for less than 1% of the certified organic fresh market tomatoes and peppers produced in the USA[9]. Limited information on crop yield potentials of organic production systems in humid, subtropical production areas such as Florida and their associated impact on soil quality have restricted consideration of organic production practices as viable alternatives to conventional systems.

Conservation tillage practices have demonstrated reduced impacts of soilborne pests and diseases, minimized agricultural inputs, and improved soil quality. No-till production in rotation with living mulches has been used successfully to produce crops of sweet corn (*Zea mays*)[10,11]. Strip-tillage in rotation with a living bahiagrass (*Paspalum notatum*) pasture was shown to be technically feasible for spring production of fresh market tomato in North Florida and Georgia[12]. No-till or strip-tillage tomato production in rotation with winter legumes is technically feasible in temperate production regions[13–16]. In these systems, winter legumes, including hairy vetch (*Vicia villosa*) and crimson clover (*Trifolium incarnatum*), are used as stubble mulch for the subsequent tomato crop. When these systems were evaluated for pepper production, inadequate weed control resulted in lower yields[17]. Conservation tillage practices using the stubble remaining from a summer legume have not been evaluated for the fall production of fresh market tomatoes or peppers in humid, subtropical regions.

Soil solarization is a natural, hydrothermal process that uses transparent plastic film to capture radiant heat in the soil. When extended over a 6- to 8-week period of long daylength and high ambient temperature, the heat accumulated in the soil can lead to the control of many key soilborne pests. Soil solarization has been adapted to conventional fresh market tomato and pepper production in humid subtropical climates and shown to be technically feasible[18–20]. It has also been combined with the application of organic amendments to improve its level of efficacy[21]. Although soil solarization is well adapted for use in organic production systems, its impact on crop production and soil quality is not extensively documented for humid, subtropical climates.

The objectives of this study were to measure the impacts of selected alternative production practices on the yield potential of fresh market peppers and several indicators of soil quality in a humid, subtropical production region. To generate valid information for organic producers and those transitioning to organic production, experimental sites were selected on commercial conventional and organic farms. To minimize variability due to the source of nitrogen and to comply with organic regulations at one of the experimental sites, poultry litter was used as the main source of nitrogen, phosphorus and potassium in all field experiments.

Materials and Methods

Two sites were selected in southeastern Florida. The first site, located in Vero Beach, was an organic vegetable farm with continuous (5 years) and current organic certification. Before producing vegetables, this site was an abandoned grapefruit grove. The soil was a Winder fine loamy sand (hyperthermic, Typic Glossaqualfs) with a pH of 6.4 and a texture of 90%–5%–5% sand–silt–clay, respectively. Soil organic carbon, detected from samples collected at 15 cm depths using wet oxidation with $K_2Cr_2O_7$ in H_2SO_4 following the Walkley–Black procedure[22], was 37.8 t C ha^{-1}, which was within the range of 23.3 to 69.8 t C ha^{-1} reported for Winder soils[23].

The second site, located in Boynton Beach, was a conventional pepper farm in production since 1957 and fumigated with a mixture of methyl bromide–chloropicrin annually since 1973. Prior to initiation of this study, a cover crop of crabgrass (*Digitaria ciliaris*) was allowed to establish for 2 years. The soil was Myakka fine sand (hyperthermic, Aeric Haplaquad) with a pH of 7.4 and a texture of 95%–2%–3% sand–silt–clay, respectively. Soil organic carbon was 42.4 t C ha^{-1} which was above the reported range of 21.0 to 42.0 t C ha^{-1} for Myakka soils[23,24].

Experiments were conducted in 1999 and 2000. Poultry (broiler) litter was used as the source of fertilizer at both farm sites to provide a consistent source of slow-release N that conformed to organic production standards. The broiler litter consisted of a mixture of chicken manure and pine shavings collected from commercial broiler production houses and composted in static windrows. It was broadcast to fields at a rate of 22 t ha^{-1} and immediately disked to a depth of 12–15 cm. Applications were made on 14 June 1999 and 16 June 2000 at the organic farm site, and on 7 July 1999 and 24 July 2000 at the conventional farm site. The poultry litter analysis averaged 17% ash, 3.3% total nitrogen, 0.9% ammonia nitrogen, 1% elemental P and 2% elemental K. Thus, the corresponding application rates were 726 kg N, 220 kg elemental P (504 kg P_2O_5), and 440 kg elemental K (528 K_2O) per hectare. High rates were used because of an estimated loss of 30% N during application and high mineralization rates in Florida soils.

The experiment was designed as a split plot, with main plots as urban plant debris (UPD) applied at 0 or 67 t ha^{-1}. Urban plant debris was derived from green waste deposited at a public landfill by homeowners and small landscape maintenance companies. The UPD was tub-ground, passed through 10 and 2.5 cm mesh screens and static-piled for a minimum of 30 days. Samples were removed from piles and tested for residues of metal, chlorinated herbicides and organochlorine pesticides. Only UPD with metal residues below 10 mg kg^{-1} and herbicide and pesticide residues below 1 μg kg^{-1} was used in the study. The UPD analysis averaged 29 g N t^{-1}, 52 g P t^{-1}, 280 g K t^{-1}, 2.3 kg Ca t^{-1} and 110 g Mg t^{-1} with a pH of 7.1. The UPD was broadcast and incorporated to a depth of 15 cm immediately following the poultry litter application on 15 June 1999 and 22 June 2000 at the organic farm site, and on 8 July 1999 and 25 July 2000 at the conventional farm site.

Main plots were 60 × 7.5 m at the organic site and 75 × 10 m at the conventional site and were arranged with four replications in a randomized complete block design. Subplots were randomized within each main plot and consisted of 3 rows 15 m in length and spaced 2 m apart. Subplots were a cover crop of iron-clay pea (*Vigna unguiculata*), a cover crop of sunn hemp (*Crotalaria juncea*), soil solarization, and a white over black, co-extruded, low-density polyethylene (LDPE) plastic mulch (Pliant Corp., Schaumburg, Illinois). Subplot treatments were implemented on 90 cm wide × 25 cm tall beds. At the organic farm site, subplot treatments were initiated on 18 June 1999 and 27 June 2000. Cover crops were seeded by drilling seed in two rows spaced 30 cm apart using a seeding rate of 45 kg ha^{-1} and were mowed 60 and 64 days after seeding with a high-speed flail mower. Soil solarization was terminated after 56 days in 1999 and 65 days in 2000 by painting the plastic white, thus enabling it to be used as an agricultural mulch[18].

Identical subplot treatments were applied at the conventional site except that an additional soil fumigation subplot was added, using a 67 : 33 mixture of methyl bromide–chloropicrin, applied at 400 kg ha^{-1} to a depth of 25 cm using three shanks spaced 25 cm apart. Immediately after fumigation, the raised beds were covered with white over black LDPE mulch. Subplot treatments were applied on 22 July 1999 and 30 July 2000. Cover crops were mowed 65 days after planting. Soil solarization was terminated after 56 days in 1999 and 66 days in 2000.

Six-week-old pepper seedlings (‘Enterprise’) were transplanted into subplots at the organic farm site on 25 August 1999 and 2 September 2000. Two rows were planted 20 cm from the edge of the bed. Plant spacing within rows was 25 cm. In the subplots where the cover crops were mowed, pepper seedlings were transplanted into the stubble without tilling the soil (no-till). In the conventional site, 6-week-old ‘Enterprise’ seedlings were planted on 27 September 1999 and 9 October 2000, using the same row and plant spacing.

Ten soil cores (15-cm depth) were collected randomly from the center bed in each subplot and combined into a composite sample for chemical analysis. At the organic farm site, samples were collected 60 and 17 days after initiation of treatments in 1999 and 2000, respectively. At the conventional farm site, samples were collected 32 and 21 days after initiation of treatments in 1999 and 2000, respectively. Soil pH was determined using a 1 : 2 dilution of soil to water. Soil organic carbon (SOC) was determined using wet oxidation with $K_2Cr_2O_7$ in H_2SO_4 following the Walkley–Black procedure[22]. Samples were sieved prior to testing to remove organic debris. A soil test for phosphorus levels was conducted using the Weak Bray extraction method[25]. Elemental K, Ca and Mg were determined by atomic absorption after extraction with 1.0 *M* ammonium acetate (pH 7.0). Cation exchange capacity (CEC) and base saturation were calculated from exchangeable cation concentrations at pH 7.0. Soil analyses were conducted by A&L Southern Agricultural Laboratories (Pompano Beach, Florida).

Stand counts were determined 21–28 days after transplanting peppers by counting the number of surviving transplants. Yields were determined by harvesting all peppers from 24 contiguous, healthy plants located in the center row of each plot between 76 and 106 days after transplanting. Fruit was evaluated in the field for marketability based upon USDA grading standards for size and appearance. Marketable fruit were weighed and yield was determined. Results from each farm site by year combination were analyzed separately. Analysis of variance (ANOVA) was performed to determine the influence of UPD and production practices on soil quality indicators and marketable yield using the general linear models procedure in STATISTICA (StatSoft, Inc., Tulsa, Oklahoma).

Results

In 1999, incorporation of urban plant debris to the soil significantly lowered levels of soil NO_3-N at both farm sites (Tables 1 and 2). There was a significant interaction between urban plant debris and production practices at the conventional farm site, with the highest levels observed in the methyl bromide and soil solarization treatment that did not receive urban plant debris. The lowest levels were recorded in the no-till and plastic mulch treatment that received urban plant debris. In 2000, soil NO_3-N levels were not affected by addition of urban plant debris or production practices.

Soil P levels were high at both farm sites and were not affected by any treatment (Tables 1 and 2). Soil pH was significantly affected by the interaction between crop production practices and the addition of UPD at both sites in 1999 and at the conventional site in 2000 (Tables 1

Table 1. Effect of urban plant debris and production practices on surface soil (15 cm) quality indicators at the conventional farm site.

Production practice	NO_3-N (kg ha^{-1})			P (kg ha^{-1})			pH			Organic carbon (Mg ha^{-1})		
	UPD(+)[1]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UDP(–)	Mean
1999												
White plastic mulch	18.8 a[2]	42.5 c	30.6	314.3	307.2	310.7	7.6 cd	7.4 bc	7.5	46.4	35.4	40.9
Soil solarization	26.1 ab	70.9 d	48.5	324.8	264.4	294.6	7.7 d	7.0 a	7.4	41.8	35.2	38.5
No-till (sunn hemp)	16.5 a	15.5 a	16.0	296.1	276.8	286.4	7.4 bcd	7.3 b	7.4	38.0	35.7	36.8
No-till (iron-clay pea)	16.6 a	20.1 a	18.4	288.5	315.0	301.8	7.2 ab	7.2 ab	7.3	36.3	38.1	37.2
Methyl bromide	34.5 bc	68.0 d	51.2	284.9	315.6	300.3	7.5 bcd	7.0 a	7.3	41.5	40.9	41.2
Mean	22.5	43.4	–	301.7	295.8	–	7.5	7.2	–	40.8	37.0	–
2000												
White plastic mulch	60.7	45.7	53.2	211.0	210.8	210.9	7.6 bc	7.6 bc	7.5	56.7	30.8	43.8
Soil solarization	65.1	61.1	63.1	215.8	192.5	204.2	7.5 bc	7.6 bc	7.5	46.2	36.6	41.4
No-till (sunn hemp)	38.3	65.6	52.0	236.3	226.7	231.5	7.6 bc	7.1 a	7.4	52.3	38.4	45.4
Methyl bromide	56.7	56.8	56.7	196.3	226.8	211.6	7.8 c	7.4 b	7.6	55.8	33.6	44.5
Mean	51.0	58.6	–	217.1	221.3	–	7.6	7.3	–	52.2A[3]	35.1 B	–

[1] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[2] Values followed by a lower-case letter indicate a significant interaction ($P = 0.05$) between urban plant debris and production practice. Values followed by the same letter are not significantly different at $P = 0.05$.
[3] Values followed by an upper-case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.

Table 2. Effect of urban plant debris and production practices on surface soil (15 cm) quality indicators at the organic farm site.

Production practice	NO_3-N (kg ha^{-1})			P (kg ha^{-1})			pH			Organic carbon (Mg ha^{-1})		
	UPD(+)[1]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UDP(–)	Mean
1999												
White plastic mulch	79.5	108.3	64.3	219.8	211.2	215.5	7.0 d[2]	6.3 a	6.7	38.6	34.7	36.6
Soil solarization	69.0	92.5	51.2	212.3	207.4	209.8	6.8 cd	6.8 cd	6.8	34.9	27.6	31.2
No-till (sunn hemp)	75.3	96.3	56.3	235.8	227.3	231.6	7.0 e	6.6 b	6.8	41.2	33.7	37.5
No-till (iron-clay pea)	60.3	106.4	53.8	225.9	193.8	209.8	6.9 cd	6.5 b	6.7	38.3	30.3	34.3
Mean	71.1A[3]	100.9 B	–	223.4	209.9	–	6.9	6.5	–	38.3 A	31.6 B	–
2000												
White plastic mulch	28.9	30.5	29.7	329.8	318.7	324.2	7.4	7.3	7.3 B	55.1	39.0	47.0
Soil solarization	20.8	23.7	22.2	289.7	307.4	298.5	7.5	7.2	7.4 B	51.3	37.5	44.4
No-till (sunn hemp)	38.9	36.4	37.7	293.2	300.3	296.8	7.1	6.9	7.0 A	56.0	40.5	48.2
No-till (iron-clay pea)	36.1	26.6	31.4	325.3	304.6	314.9	7.1	7.1	7.0 A	68.4	37.8	53.2
Mean	31.2	29.3	–	309.5	307.7	–	7.2	7.1	–	57.8 A	38.7 B	–

[1] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[2] Values followed by a lower case letter indicate a significant interaction ($P = 0.05$) between urban plant debris and production practice. Values followed by the same letter are not significantly different at $P = 0.05$.
[3] Values followed by an upper case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.

and 2). Soil pH was lowest in the no-till treatments and increased with the addition of UPD. Soil pH was highest in treatments where urban plant debris was combined with the use of LDPE mulch.

Addition of urban plant debris did not impact soil organic carbon levels at the conventional farm site in 1999 (Table 1). Soil organic carbon levels were higher than the maximum range reported for the soil type at the conventional farm site[23,24] and may have been due to the 2-year fallow period with a crabgrass cover crop prior to initiation of the experiment, and the addition of organic materials during transition to a biorational farm management system[26]. In 2000, addition of urban plant debris significantly increased soil organic carbon at the conventional site. Urban plant debris significantly increased soil organic carbon in both years at the organic farm site (Table 2). Soil organic carbon levels at the organic farm site were within the range reported for the soil type in treatments that did not receive any urban plant debris.

The CEC significantly increased after the addition of urban plant debris to the soil in both years at both sites (Tables 3 and 4). Production practices significantly affected

Table 3. Effect of urban plant debris and production practices on cation exchange capacity (CEC) and percent base saturation at the conventional farm site.

Production practice	CEC[1]			% Ca			% Mg			% K		
	UPD(+)[2]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean
1999												
White plastic mulch	10.6	9.2	9.9 A[3]	80.5	82.6	81.6 A	12.0	11.7	11.8	7.6	5.6	6.6 BC
Soil solarization	10.3	9.0	9.7 A	78.8	83.3	81.0 A	12.5	11.4	12.0	8.8	5.1	6.9 BC
No-till (sunn hemp)	9.8	8.8	9.3 A	84.6	86.2	85.4 A	12.4	10.7	11.6	3.0	3.0	3.0 AB
No-till (iron-clay pea)	10.0	8.9	9.4 A	87.6	86.3	87.0 A	10.3	11.6	11.0	1.8	1.9	1.9 A
Methyl bromide	13.3	10.8	12.0 B	69.7	73.9	71.8 B	23.4	11.2	17.3	6.7	13.4	10.0 C
Mean	10.8 A	9.4 B	–	80.2	82.5	–	14.1	11.3	–	5.6	5.8	–
2000												
White plastic mulch	8.7	7.1	7.9	80.8	82.0	81.4	11.6	11.0	11.3	7.8	6.6	7.2 AB
Soil solarization	8.8	7.6	8.2	81.5	81.9	81.7	10.8	10.7	10.7	7.6	7.6	7.6 AB
No-till (sunn hemp)	9.0	7.3	8.1	81.6	80.3	80.9	11.2	12.0	11.6	7.5	7.3	7.4 AB
No-till (iron-clay pea)	8.7	6.6	7.7	84.5	81.0	82.7	10.0	10.0	10.0	5.4	7.0	6.2 A
Methyl bromide	8.6	7.3	8.0	76.4	82.4	79.4	12.1	10.5	11.3	11.4	7.0	9.2 B
Mean	8.8 A	7.2 B	–	81.0	81.5	–	11.1	10.8	–	8.0	7.1	–

[1] Measured in meq per 100 g soil.
[2] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[3] Values followed by an upper case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.

Table 4. Effect of urban plant debris and production practices on cation exchange capacity (CEC) and percent base saturation at the organic farm site.

Production practice	CEC[1]			% Ca			% Mg			% K		
	UPD(+)[2]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean
1999												
White plastic mulch	8.3	7.3	7.8 AB[3]	69.9	62.1	66.0 A	19.9	19.8	19.8	8.8	7.9	8.4 B
Soil solarization	8.0	7.1	7.5 A	70.0	66.9	68.4 B	19.1	21.4	20.3	7.8	8.6	8.2 B
No-till (sunn hemp)	8.6	7.9	8.2 B	71.2	66.8	69.0 B	20.5	20.2	20.3	7.1	6.1	6.6 A
No-till (iron-clay pea)	9.2	7.3	8.2 B	70.8	67.9	69.4 B	19.1	19.8	19.4	8.2	4.2	6.2 A
Mean	8.5 A	7.4 B	–	70.5 A	65.9 B	–	19.6	20.3	–	8.0 A	6.7 B	–
2000												
White plastic mulch	7.8 cd[4]	6.1 a	6.9	70.6	68.2	69.4	19.9	21.5	20.7	9.2	10.3	9.7
Soil solarization	7.1 bc	6.8 ab	6.9	70.2	67.6	68.9	20.4	22.0	21.2	9.3	10.0	9.6
No-till (sunn hemp)	7.9 cd	7.1 bc	7.5	71.4	66.8	69.1	19.6	21.4	20.5	8.6	8.4	8.5
No-till (iron-clay pea)	8.6 d	6.3 ab	7.4	72.4	66.6	69.5	18.6	22.5	20.5	8.8	9.7	9.3
Mean	7.8	6.6	–	71.2 A	67.3 B	–	19.6 A	21.9 B	–	9.0	9.6	–

[1] Measured in meq per 100 g soil.
[2] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[3] Values followed by an upper case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.
[4] Values followed by a lower case letter indicate a significant interaction ($P = 0.05$) between urban plant debris and production practice. Values followed by the same letter are not significantly different at $P = 0.05$.

the cation-exchange capacity at both sites in 1999. A significant interaction between urban plant debris and production practices on the CEC was observed at the organic site in 2000 (Table 4).

Calcium dominated the base saturation ratio at both farm sites but was 10% higher in the conventional farm site (Tables 3 and 4). Addition of urban plant debris increased the calcium ratio at the organic farm site. In 1999, the percentage of potassium ions in the base saturation ratio was significantly higher at both farm sites when plastic mulch was used.

The number of pepper seedlings remaining 21–28 days after transplanting was significantly higher when plastic mulch was used as the production practice (Figs. 1 and 2).

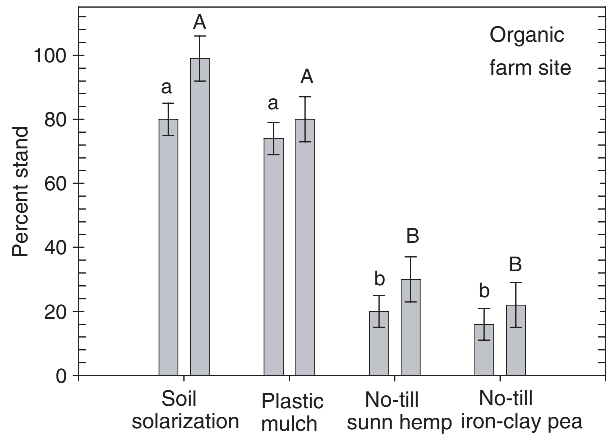

Figure 1. Mean and standard error for the effect of production practices on the survival of pepper seedlings 21–28 days after transplanting (percent stand). Similar lower-case letters indicate no significant difference ($P = 0.05$) among means in 1999. Similar upper-case letters indicate no significant difference ($P = 0.05$) in 2000. The addition of urban plant debris did not have a significant effect. No interaction between urban plant debris and production practice was observed.

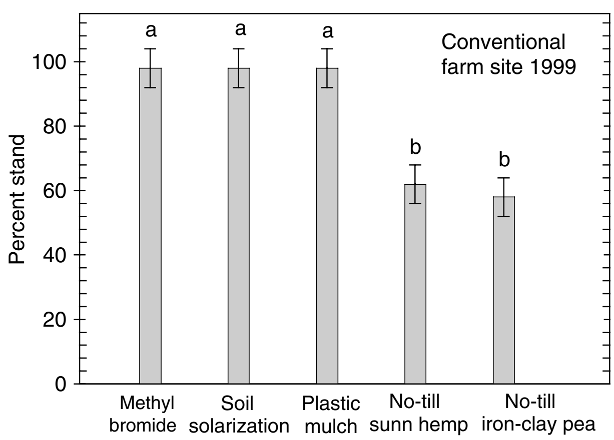

Figure 2. Mean and standard error for the effect of production practices on the survival of pepper seedlings 21–28 days after transplanting (percent stand). Similar lower-case letters indicate no significant difference ($P = 0.05$) among means in 1999. Percent stand was not determined in 2000 due to an epidemic of *Phytophthora* blight. The addition of urban plant debris did not have a significant effect. No interaction between urban plant debris and production practice was observed.

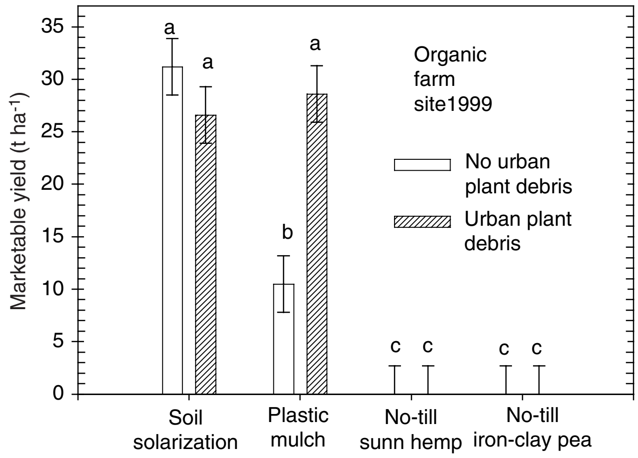

Figure 3. Mean and standard error for the interaction of urban plant debris and production practice on the marketable yield of pepper. Similar lower-case letters indicate no significant difference ($P = 0.05$) among means.

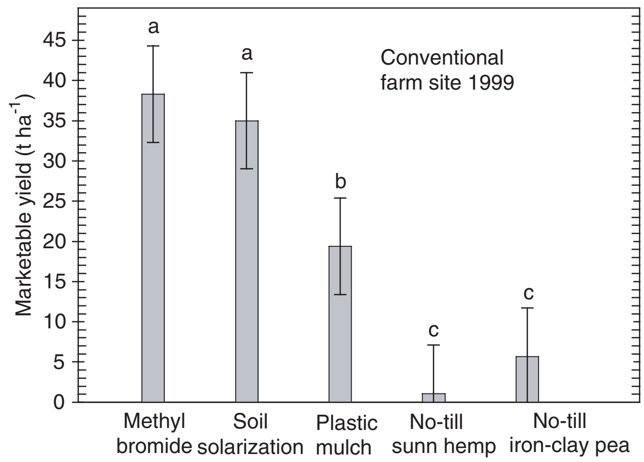

Figure 4. Mean and standard error for the effect of production practices on the marketable yield of pepper. Similar lower-case letters indicate no significant difference ($P = 0.05$) among means in 1999. Urban plant debris did not have a significant effect on yield. No significant interaction between urban plant debris and production practice was observed.

Stand reductions up to 70% were observed in the no-till treatments. Addition of urban plant debris did not affect the plant stand at either farm site, and no interaction with production practices was observed. In 2000 an epidemic of *Phytophthora* blight on the conventional farm site resulted in significant plant mortality 28 days after transplanting. Thus, no plant stands or yields were taken.

In 1999, there was a significant interaction between urban plant debris and production practices on the marketable pepper yield at the organic site (Fig. 3). Yields were highest in the soil solarization treatments and in the plastic mulch treatment where urban plant debris was incorporated into the soil. Yield was intermediate in the plastic mulch treatment without the addition of urban plant debris and lowest in the no-till treatments. In 1999, only production practices had a significant impact on marketable yield at the conventional farm site (Fig. 4). Yields were highest in the methyl bromide and soil solarization treatments, intermediate in the plastic mulch treatment and lowest in the no-till treatments. In 2000, production practices also significantly impacted yield at the organic site (Fig. 5). Yields were highest in the soil solarization treatment, intermediate in the plastic mulch treatment and lowest in the no-till treatments. No significant interaction between production practices and urban plant debris was observed. No plants were harvested in the conventional site in 2000 due to the epidemic of *Phytophthora* blight.

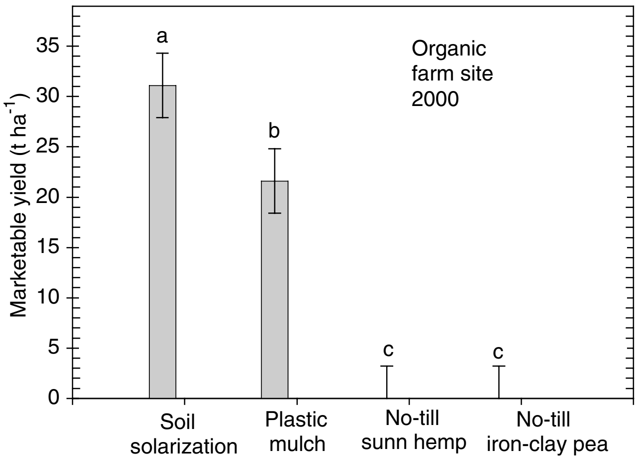

Figure 5. Mean and standard error for the effect of production practices on the marketable yield of pepper. Similar lower-case letters indicate no significant difference ($P = 0.05$) among means. No significant effect of urban plant debris or interaction was observed.

Discussion

No-till production of pepper in mulch provided by the stubble remaining from a summer cover crop of sunn hemp or iron-clay pea crop did not sustain productivity and is not recommended as an alternative production practice in humid, subtropical production regions such as Florida. High ambient temperatures and abundant precipitation during the production season accelerated the deterioration of the stubble mulch from the cover crop after it was mowed and provided optimum conditions for the resurgence of weed populations. The resultant competition from weeds affected survival and growth of the pepper transplants. Competition from weeds has also been implicated in the poor performance of a no-till pepper production system using a legume cover crop in a temperate production region[17].

In studies comparing organic and conventional practices in Iowa, yields of pepper in organic plots were similar to yields in conventional plots over a 5-year period from 1998 to 2002[27,28]. In this study, yields in organic plots were 2–7% less than the statewide average of 35.8 t ha^{-1} reported for conventional growers in Florida over a 5-year period from 1996 to 2001[1]. No reliable data are available for yields of organic pepper growers in Florida during the same time period. At the conventional farm site, yields in soil fumigated with methyl bromide–chloropicrin exceeded the statewide average by 6% in 1999. However, no yields were obtained in fumigated plots in 2000 due to an epidemic of a soilborne disease. The results demonstrate that in Florida, organic production systems for fresh market pepper can produce yields similar to those obtained in conventional systems.

Incorporation of urban plant debris led to a reduction of soil NO_3-N in these experiments. This amendment can potentially reduce nitrate leaching into surface and ground water when poultry litter is used as the nutritional source for crop production. The addition of urban plant debris also improved soil quality by increasing soil organic carbon and cation-exchange capacity. However, these effects were not realized until the second year of the study at the conventional farm site, indicating that several years of organic amendments might be needed to measure beneficial effects. One noticeable difference in soil quality indicators between the two farms sites was the base saturation ratio of the cation exchange capacity. At the conventional site, calcium accounted for 80.2% to 82.5% of base cations. By contrast, calcium accounted for 65.9–71.2% of the cation exchange capacity at the organic farm site. The combined percentage of Na and H in both sites was less than 1%. A base saturation ratio of 65–75% Ca, 10–15% Mg, 2–5% K, 0.5–3% Na, and 10–15% H has been described as optimum for soil and plant health[29,30], although a review of over 100 published studies and experimental results over a 3-year period indicated that the benefits of proper cation balancing are site-specific[31].

Conclusions and Recommendations

Based on the results of this study, organic no-till production practices using a legume cover crop to provide a stubble mulch are not recommended for fall production of pepper in Florida. This study also demonstrated that similar pepper yields can be achieved in alternative systems using recycled, slow-release nitrogen sources compared to conventional pepper production systems relying upon high inputs of rapidly mobile nitrogen and potassium sources. Finally, the results indicate that incorporation of recycled yard wastes can improve soil quality and may help minimize detrimental effects from high applications of nitrogen in either organic or conventional forms.

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